



US012107236B2

(12) **United States Patent**  
**Hara**

(10) **Patent No.:** **US 12,107,236 B2**  
(45) **Date of Patent:** **\*Oct. 1, 2024**

(54) **SECONDARY BATTERY**

(71) Applicant: **TOYOTA JIDOSHA KABUSHIKI KAISHA**, Toyota (JP)

(72) Inventor: **Tetsuo Hara**, Toyota (JP)

(73) Assignee: **TOYOTA JIDOSHA KABUSHIKI KAISHA**, Toyota (JP)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **18/467,068**

(22) Filed: **Sep. 14, 2023**

(65) **Prior Publication Data**  
US 2023/0420746 A1 Dec. 28, 2023

**Related U.S. Application Data**

(63) Continuation of application No. 17/027,852, filed on Sep. 22, 2020, now Pat. No. 11,799,134.

**Foreign Application Priority Data**

Oct. 10, 2019 (JP) ..... 2019-186940

(51) **Int. Cl.**  
**H01M 10/0587** (2010.01)  
**H01M 50/46** (2021.01)  
**H01M 50/538** (2021.01)

(52) **U.S. Cl.**  
CPC ..... **H01M 10/0587** (2013.01); **H01M 50/46** (2021.01); **H01M 50/538** (2021.01); **Y02E 60/10** (2013.01); **Y02P 70/50** (2015.11)

(58) **Field of Classification Search**

CPC ..... H01M 10/0587; H01M 50/46; H01M 50/538; Y02P 70/50; Y02E 60/10  
(Continued)

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

2007/0224493 A1 9/2007 Higuchi et al.  
2012/0270099 A1 10/2012 Lee et al.  
(Continued)

**FOREIGN PATENT DOCUMENTS**

CN 101043090 A 9/2007  
CN 102751527 A 10/2012  
(Continued)

**OTHER PUBLICATIONS**

Tetsuo Hara, U.S. Appl. No. 17/027,852, Non-Final Rejection issued Jun. 27, 2022.

(Continued)

*Primary Examiner* — Jonathan G Jelsma

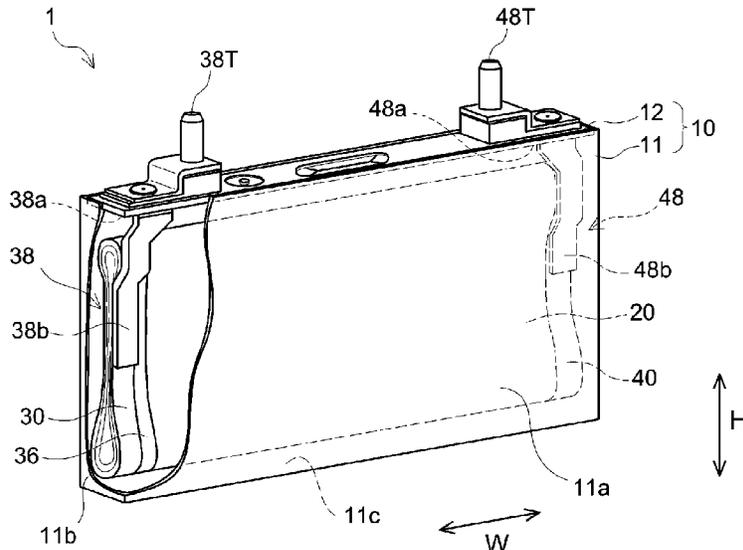
*Assistant Examiner* — Omar M Kekia

(74) *Attorney, Agent, or Firm* — Dickinson Wright, PLLC

(57) **ABSTRACT**

A secondary battery includes a battery case, an electrode body, and a collector member connecting the battery case and the electrode body. A positive electrode includes an insulation layer provided so as to be adjacent to a positive electrode active material layer. The collector members include first portions, and second portions continuous to the first portions and bent relative to the first portions. The first portions are fixed to the battery case. The second portions are connected, at ends thereof opposite to the bent portions, to collector regions, respectively. The collector members further include ribs connected, at the bent portions, to the first portions and the second portions, respectively.

**5 Claims, 6 Drawing Sheets**



(58) **Field of Classification Search**

USPC ..... 429/163

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2013/0260221	A1	10/2013	Yoshitake et al.
2015/0380712	A1	12/2015	Tsunaki et al.
2016/0043373	A1	2/2016	Arishima et al.
2019/0198910	A1	6/2019	Kondo et al.
2021/0194007	A1	6/2021	Danno

FOREIGN PATENT DOCUMENTS

CN	105190952	A	12/2015
CN	108604664	A	9/2018
JP	2009026705	A	2/2009
JP	2012227113	A	11/2012
JP	2019114423	A1	7/2019
WO	2009013592	A1	1/2009
WO	2014162437	A1	10/2014

OTHER PUBLICATIONS

Tetsuo Hara, U.S. Appl. No. 17/027,852, Non-Final Rejection issued Jan. 9, 2023.

Tetsuo Hara, U.S. Appl. No. 17/027,852, Notice of Allowance issued Jun. 16, 2023.

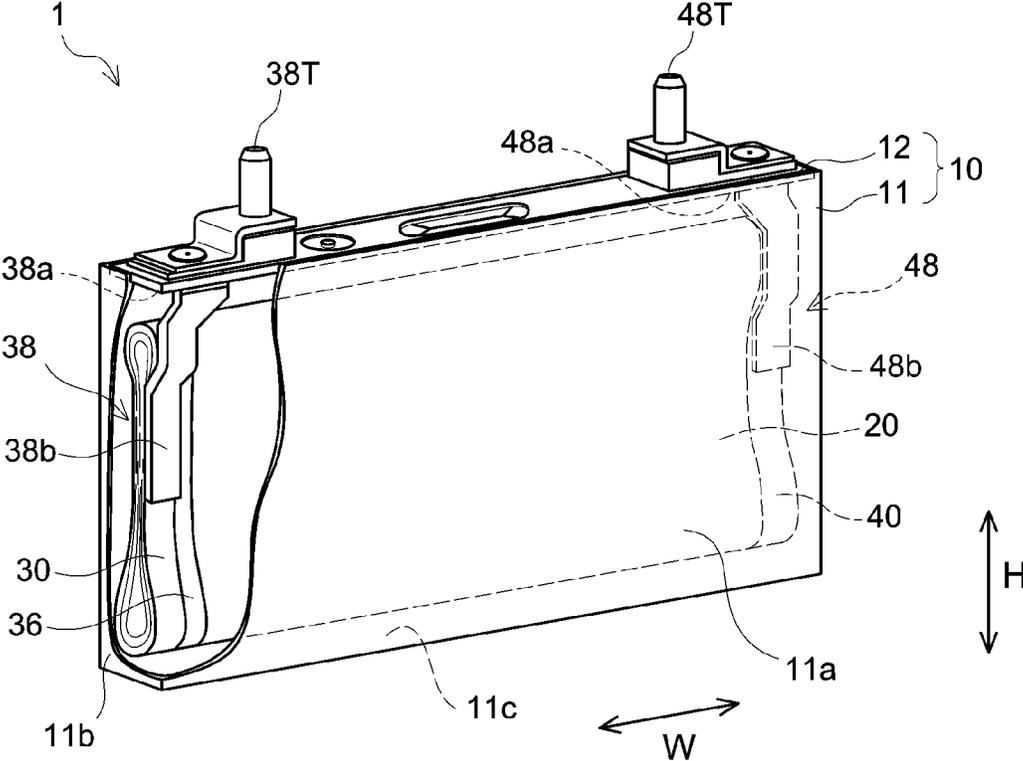


FIG. 1

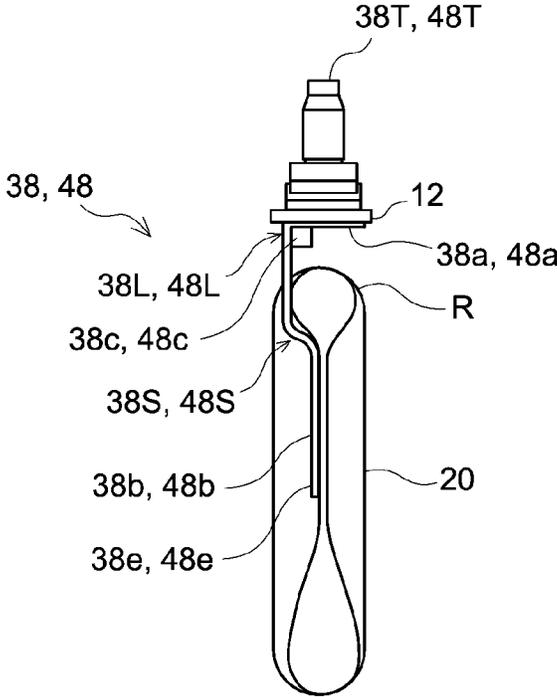


FIG.2

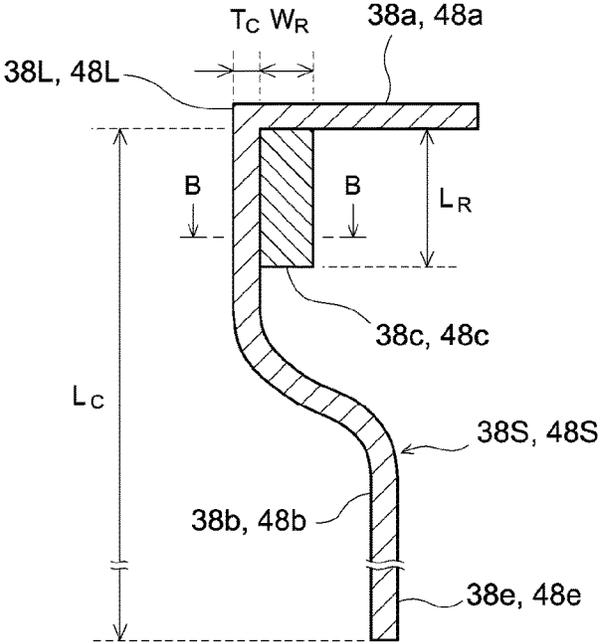


FIG.3A

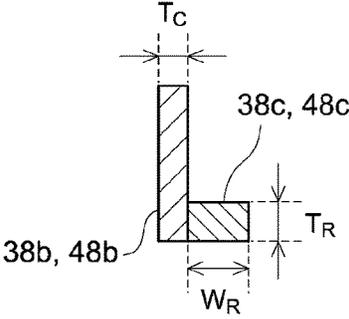


FIG.3B

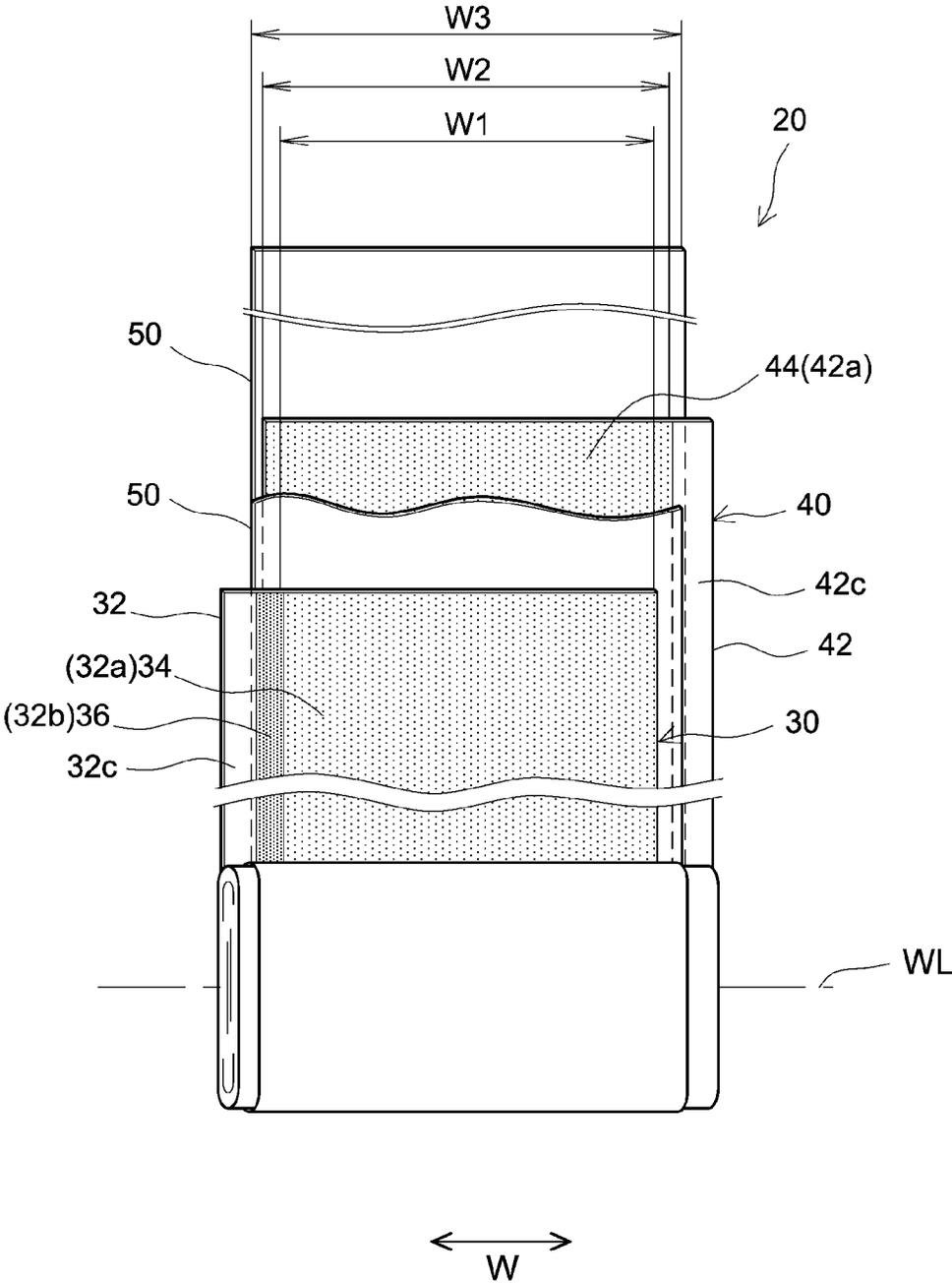


FIG.4

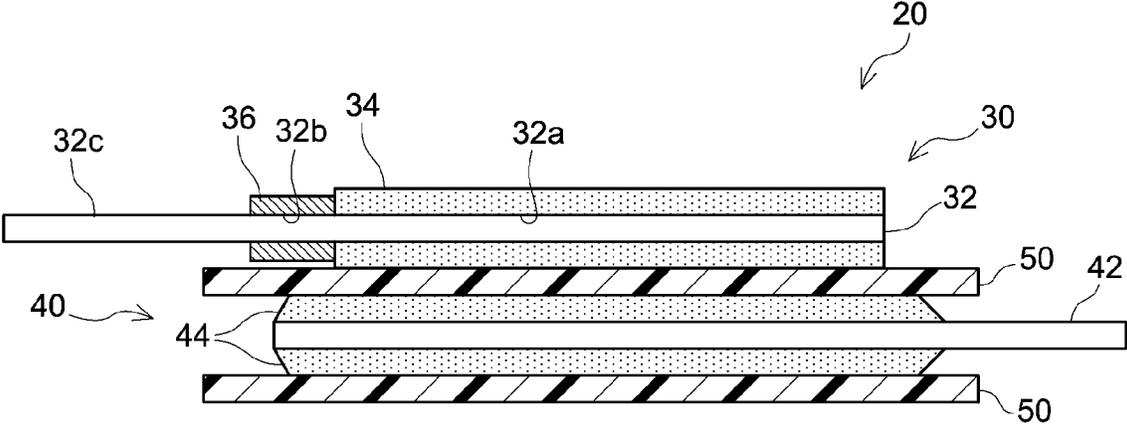


FIG.5

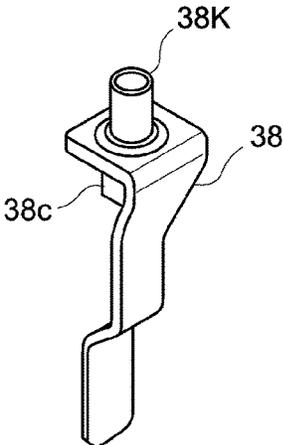


FIG. 6A

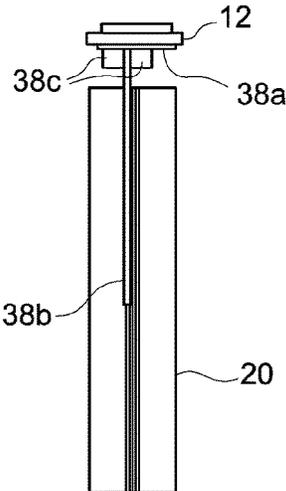


FIG. 6B

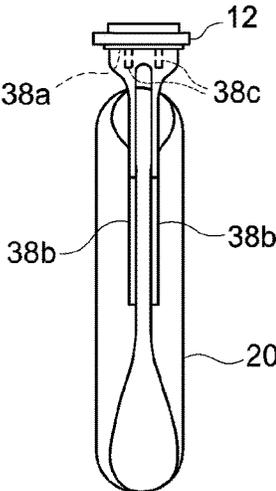


FIG. 6C

**SECONDARY BATTERY****CROSS-REFERENCE TO RELATED APPLICATIONS**

The present application is a continuation of U.S. patent application Ser. No. 17/027,852, filed Sep. 22, 2020, which claims priority to Japanese Patent Application No. 2019-186940 filed on Oct. 10, 2019, the entire contents of which are incorporated herein by reference.

**BACKGROUND****1. Field of the Invention**

The present invention relates to a secondary battery.

**2. Description of the Related Art**

Secondary batteries such as a lithium ion secondary battery and a nickel metal hydride battery have been preferably used as the power supply for driving a vehicle, other than as so-called portable power supplies for a personal computer, a portable terminal, and the like. As one example of the secondary battery, a battery is known in which an electrode body including a positive electrode and a negative electrode insulated from each other by a separator therein is accommodated in a battery case. The electrode forming the electrode body has an active material layer including an active material at the surface of a collector foil. Herein, in order to enhance the receivability of the electric charge carrier of a negative electrode active material layer of the low potential side, the negative electrode active material layer is designed so as to have a larger area than that of the positive electrode active material layer.

In this case, the negative electrode active material layer protruding from the positive electrode active material layer has a high deformation freedom degree. Accordingly, the corner part of the end of the negative electrode active material layer may break the separator, and may be short-circuited with the uncoated part not including a positive electrode active material of the positive electrode collector foil. For example, WO 2014/162437 discloses a configuration in which an insulation layer is included in the portion opposed to the negative electrode active material layer in the region of the positive electrode collector foil adjacent to the positive electrode active material layer in order to suppress such a short circuit.

**SUMMARY**

However, observation of the secondary battery actually used has shown that cracking or peeling may be caused in the insulation layer provided adjacent to the positive electrode active material layer. Further, it has become obvious that the insulation layer becomes more likely to be peeled with an increase in cracks of the insulation layer. Peeling of the insulation layer is desired to be improved in terms of the reduction of the insulation property between the negative electrode active material layer and the positive electrode collector foil.

The present invention has been made in view of such circumstances, and an object of the present invention is to provide a secondary battery in which occurrence of cracking and peeling of the insulation layer provided along the positive electrode active material layer is suppressed.

A study by the present inventors indicated that cracking and peeling of the insulation layer provided at the positive electrode collector is largely affected by the vibration of the battery. Namely, in one typical example of the secondary battery, the electrode body is positioned in the battery case by bonding (e.g., welding) the positive electrode side collector part and the negative electrode side collector part to the positive and negative collector members made of a metal attached to the lid member, respectively. However, the electrode body is fixed only at the welded part with the collector member, and may move or may be deformed at other parts. Then, the electrode body is the thickest at the overlapping portion of the positive electrode active material layer and the negative electrode active material layer. The collector portion without the positive electrode active material layer is less restrained by that much, resulting in a higher deformation freedom degree as compared with the portion. For this reason, conceivably, when a battery vibrates, a deviation is caused in vibration between the electrode body and the tip of the collector member; accordingly, a load is concentrated to the insulation layer provided at the collector part with a high deformation freedom degree of the electrode body; this causes cracking and peeling of the insulation layer.

Thus, as the one for solving the problem, a secondary battery herein disclosed includes: a battery case; an electrode body in which a positive electrode, a negative electrode, and a separator are stacked, with the positive electrode and the negative electrode being insulated from each other by the separator; and a collector member connected to the battery case and the electrode body. The positive electrode includes: a positive electrode collector including an active material layer forming region, an insulation layer forming region adjacent to the active material layer forming region, and a collector region adjacent to the insulation layer forming region, a positive electrode active material layer including a positive electrode active material provided on a surface of the active material layer forming region, and an insulation layer provided on a surface of the insulation layer forming region. Further, the collector member includes: a first portion, and a second portion continuous to the first portion and bent relative to the first portion. The first portion is fixed to the battery case, and the second portion is connected, at an end thereof on an opposite side to the bent portion, to the collector region. Then, the collector member further includes a rib connected, at the bent part, to the first portion and the second portion.

With the configuration, the rib is placed across the first portion and the second portion of the collector member. This suppresses the first portion and the second portion from being deformed in a direction in which the mutually formed angle decreases and a direction in which the angle increases. As a result, when a secondary battery receives a vibration, the deviation in vibration of the second portion fixed to the electrode body with respect to the vibration of the first portion fixed to the case is suppressed. This can reduce the occurrence of cracking or peeling at the insulation layer onto which the difference in vibration is concentrated. From the viewpoint that such a collector member can effectively reduce the occurrence of cracking or peeling of the insulation layer, the collector member is preferably applied to the positive electrode collector member to be bonded to the positive electrode collector provided with the insulation layer. Further, from the viewpoint that such a collector member can more stably support the electrode body and can further reduce the occurrence of cracking or peeling of the insulation layer, the collector member is preferably applied

to both of the positive electrode collector member and the negative electrode collector member.

Incidentally, the difference in vibration between the first portion and the second portion of the collector member can also be reduced by enhancing the rigidity of the collector member, e.g., manufacture of the collector member using a hard material, or increasing the thickness of the member. However, a material having a higher rigidity (e.g., Young's modulus) than that of the constituent material (typically, Al or Al alloy, or Cu or Cu alloy) of a general collector member is not desirable in terms of its high electric resistance. Further, it can be said that the increase in thickness of the collector member is undesirable from the viewpoint of the cost.

Incidentally, Japanese Patent Application Publication No. 2009-026705 discloses as follows: in order to suppress the collector terminal from being deformed by a pressing force during welding between the electrode body and the collector member, and damaging the collector, the flat part including the bonding surface of the collector member to be bonded to the collector is bent. With such a configuration, although the rigidity of the bonding surface of the collector member is enhanced, peeling of the insulation layer cannot be suppressed. In terms of this point, the present invention is clearly distinguishable in configuration and technical idea from the disclosure of Japanese Patent Application Publication No. 2009-026705.

In accordance with one preferable aspect of the technology herein disclosed, the rib is connected, among surfaces of the first portion and the second portion, to a surface on an opposite side to the electrode body. This can effectively suppress the difference in vibration of the collector with respect to the battery case.

In accordance with one preferable aspect of the technology herein disclosed, the collector member includes the first portion, the second portion, and the rib, which are continuously and integrally formed, and is at least one of a bent product and a pressed product of a sheet-shaped metal. As a result, a high-strength rib can be constructed. Further, this aspect is also preferable in that the collector member can include the rib at a low cost and with efficiency.

In accordance with one preferable aspect of the technology herein disclosed, the battery case is a square battery case including a case main body having an opening, and a lid member for covering the opening. The first portion is connected to an inner surface of the lid member, and the second portion is bent along any one surface of the case main body surrounding the opening. Then, a length  $L_C$  from the first portion to an extreme end of the end and a length  $L_R$  of a dimension of the rib in a direction along the length  $L_C$  satisfy following relationship:  $L_R \geq 0.1 \times L_C$ . With the configuration, it is possible to form a rib capable of effectively suppressing the vibration of the tip part of the collector member.

In accordance with one preferable aspect of the technology herein disclosed, the battery case is a square battery case including a case main body having an opening, and a lid member for covering the opening. The first portion is connected to an inner surface of the lid member, and the second portion is bent along any one surface of the case main body surrounding the opening. Then, a thickness  $T_C$  (mm) of a dimension in a direction orthogonal to the one surface of the second portion and a thickness  $T_R$  (mm) of a dimension in a direction in parallel with the one surface of the rib satisfy following relationship:  $T_R \geq 0.4 \times 1/T_C$ . Also with such a configuration, it is possible to effectively sup-

press the bending of the collector member when the secondary battery receives a vibration.

In accordance with one preferable aspect of the technology herein disclosed, the battery case is a square battery case including a case main body having an opening, and a lid member for covering the opening. The first portion is connected to an inner surface of the lid member, and the second portion is bent along any one surface of the case main body surrounding the opening. Then, a thickness  $T_C$  (mm) of a dimension in a direction orthogonal to the one surface of the second portion and a width  $W_R$  (mm) of a dimension in a direction along the thickness  $T_C$  of the rib satisfy following relationship:  $W_R \geq 0.25 \times 1/T_C$ . As a result, it is possible to effectively suppress the bending of the collector member when the secondary battery receives a vibration.

In accordance with one preferable aspect of the technology herein disclosed, the electrode body is a wound type electrode body in which the positive electrode, the negative electrode, and the separator which are lengthy are stacked and wound. The wound type electrode body includes a curved part by winding, and hence incurs a higher load at the bonding part with the collector member than that of a sheet type electrode body including a plurality of sheet-shaped positive electrode, separator, and negative electrode stacked therein. Therefore, the configuration herein disclosed is useful because the configuration clearly produces its effect by being applied to a secondary battery including a wound type electrode body.

The secondary battery described up to this point may remarkably produce its advantageous effects, for example, when used under such environment as to be applied with a vibration. Further, the short circuit between the negative electrode active material layer and the positive electrode collector tends to become problematic for a battery in which the thickness of the electrode body is large, and the end of the negative electrode active material layer tends to be applied with a bending force, in other words, a high capacity battery. Further, a reliable measure for suppressing the short circuit has been demanded. Still further, measures have been demanded particularly for suppressing the battery temperature rise due to the microscopic short circuit in a secondary battery for uses requiring high safety. From such a viewpoint, the secondary battery herein disclosed can be in particular preferably used as power supply (main power supply) for driving a vehicle, especially, power supply for driving a hybrid vehicle, a plug-in hybrid vehicle, an electric vehicle, or the like.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cutaway perspective view schematically showing a configuration of a secondary battery in accordance with one embodiment;

FIG. 2 an essential part side view of the secondary battery in accordance with one embodiment;

FIG. 3A is a side view of a collector member in accordance with one embodiment, and FIG. 3B is a cross sectional view along B-B in FIG. 3A;

FIG. 4 is a partially developed view for illustrating a configuration of a wound type electrode body in accordance with one embodiment;

FIG. 5 is a cross sectional schematic view for illustrating a configuration of an electrode body in accordance with one embodiment; and

FIGS. 6A, 6B, and 6C are schematic views for illustrating a configuration of each collector member in accordance with other embodiments, respectively.

#### DETAILED DESCRIPTION

Below, one embodiment of a secondary battery herein disclosed will be described. Incidentally, matters necessary for executing the present invention (e.g., a structure of the secondary battery not featuring the present invention), except for matters specifically referred to in the present specification (e.g., configurations, and the like of an insulation layer and a collector member) can be grasped as design matters of those skilled in the art based on the related art in the present field. The present invention can be executed based on the contents disclosed in the present specification and the technical common sense in the present field. Further, the dimensional relation (such as length, width, or thickness) in each drawing shown below does not reflect the actual dimensional relation. Then, an expression “A to B” indicating the numerical value range in the present specification means “A or more and B or less”.

In the present specification, “secondary battery” is a term denoting an electric storage device capable of repeatedly charging and discharging in general, and including a so-called storage battery such as a lithium ion battery, a sodium ion secondary battery, or a lithium polymer battery, and electric storage elements such as an electric double layer capacitor. Further, “nonaqueous electrolyte secondary battery” is a secondary battery implementing charging and discharging using a nonaqueous electrolyte as an electric charge carrier. The electrolyte may be any of a solid electrolyte, a gel electrolyte, and a nonaqueous electrolyte. Further, the “active material” represents a substance capable of reversibly occluding and releasing chemical species serving as an electric charge carrier in a secondary battery. Below, the present technology will be described by taking the case where a nonaqueous electrolyte secondary battery is a lithium ion secondary battery as an example.

FIG. 1 is a cutaway perspective view showing a configuration of a lithium ion battery (which will be simply referred to as a “secondary battery”) **1** in accordance with one embodiment. FIG. 2 is an essential part side view thereof. FIG. 3A is a side view showing a configuration of a collector terminal, and FIG. 3B is a B-B cross sectional view thereof. FIG. 4 is a partially developed view for illustrating a configuration of a wound type electrode body **20**, and FIG. 5 is a cross sectional view thereof. W in the drawing indicates the width direction of a battery case **10** and a wound type electrode body **20**, and is in agreement with the direction of a winding axis WL of the wound type electrode body **20**. H represents the height direction of the battery case **10**. Further, the winding axis WL and the direction orthogonal to the height direction of the battery case **10** may be referred to as the thickness directions of the battery case **10** and the wound type electrode body **20**. However, the directions do not restrict the setting aspects of the secondary battery at all.

The lithium ion secondary battery **1** is configured such that the wound type electrode body **20** including the positive electrode **30**, the negative electrode **40**, and the separator **50** is accommodated in the battery case **10** together with a nonaqueous electrolyte not shown. The wound type electrode body **20** has a shape in which the separator **50**, the negative electrode **40**, the separator **50**, and the positive electrode **30** are sequentially stacked in this order, and are wound in an elliptical shape in cross section about the

winding axis WL as the center. For the electrode body **20**, respective collector regions **32c** and **42c** of collectors **32** and **42** described later protrude to both ends in the width direction. The electrode body **20** is connected to the collector members **38** and **48** at the collector regions **32c** and **42c**, respectively, and is fixed to the battery case **10**.

The positive electrode **30** typically includes the positive electrode collector **32**, and porous, and an insulation layer **36** is included therein so as to be adjacent to the positive electrode active material layer **34**. The positive electrode collector **32** is a support member of the positive electrode active material layer **34**, and can be a conductive member for extracting electric charges from the positive electrode active material layer **34**. For the positive electrode collector **32**, for example, metal foil such as aluminum (including aluminum alloy) foil is preferably used. The positive electrode collector **32** includes an active material layer forming region **32a**, an insulation layer forming region **32b**, and a collector region **32c**. The active material layer forming region **32a** occupies the most part of the positive electrode collector **32**, the insulation layer forming region **32b** is adjacent to the active material layer forming region **32a**, and the collector region **32c** is adjacent to the insulation layer forming region **32b**. The positive electrode collector **32** of this example is long, and is divided in the width direction in the order of the active material layer forming region **32a**, the insulation layer forming region **32b**, and the collector region **32c**. As one example, the dimension in the width direction of the insulation layer forming region **32b** is about 2.7 to 6 mm, and the dimension in the width direction of the collector region **32c** is about 8.5 to 12.5 mm. The positive electrode active material layer **34** is formed in a band shape on the surface of the active material layer forming region **32a**. The insulation layer **36** is formed in a band shape on the surface of the insulation layer forming region **32b**. In the collector region **32c**, the collector is exposed.

The positive electrode active material layer **34** contains a particulate positive electrode active material. The positive electrode active material layer **34** is configured as follows: positive electrode active materials are bound to one another by a binder, and are bound to the active material layer forming region **32a**. The pores of the positive electrode active material layer **34** are impregnated with a nonaqueous electrolyte. As the positive electrode active materials, for example, one or combinations of two or more of lithium transition metal composite oxides such as lithium nickel cobalt manganese composite oxides (e.g.,  $\text{LiNi}_{1/3}\text{Co}_{1/3}\text{Mn}_{1/3}\text{O}_2$ ), lithium nickel composite oxides (e.g.,  $\text{LiNiO}_2$ ), lithium cobalt composite oxides (e.g.,  $\text{LiCoO}_2$ ), and lithium nickel manganese composite oxides (e.g.,  $\text{LiNi}_{0.5}\text{Mn}_{1.5}\text{O}_4$ ) capable of reversibly occluding/releasing lithium ions are used. The positive electrode active material layer **34** can contain, other than the positive electrode active material, a conductive material such as acetylene black (AB), a binder such as an acrylic polymer, polyvinylidene fluoride (PVDF), or styrene butadiene rubber (SBR) for binding these, and other additives.

The thickness of the positive electrode active material layer **34** after pressing (which is the average thickness; the same shall apply hereinafter.) can be set at typically 10  $\mu\text{m}$  or more, for example, 15  $\mu\text{m}$  or more, and typically 50  $\mu\text{m}$  or less, 30  $\mu\text{m}$  or less, for example, 25  $\mu\text{m}$  or less. Further, the density of the positive electrode active material layer **34** has no particular restriction, and can be set at typically 1.5  $\text{g}/\text{cm}^3$  or more, for example, 2  $\text{g}/\text{cm}^3$  or more and 3  $\text{g}/\text{cm}^3$  or less, and for example, 2.5  $\text{g}/\text{cm}^3$  or less.

Incidentally, in the present specification, "average particle diameter" represents the cumulative 50% particle diameter ( $D_{50}$ ) in the volume-based particle size distribution obtained by the laser diffraction scattering method unless otherwise specified.

The insulation layer **36** has electric insulation property, and is configured so as to be able to prevent a short circuit between the end of the negative electrode active material layer **44** and the positive electrode collector **32**, for example, even when the separator **50** is broken, or the separator **50** is dissolved/shrunk, or the like. The insulation layer **36** is configured such that inorganic fillers are mutually bound by a binder, and bound with the insulation layer forming region **32b**. The insulation layer **36** may be a porous layer enabling passage of electric charge carriers therethrough. The insulation layer **36** is provided in the region adjacent to the positive electrode active material layer **34**, and opposed to at least the negative electrode active material layer **44**. The insulation layer **36** may protrude outwardly of the negative electrode active material layer **44** in the width direction by a dimension  $\alpha$ . The dimension  $\alpha$  is designed at the dimension capable of allowing sufficient covering of the end of the negative electrode active material layer **44** by the insulation layer **36** so as to avoid the situation in which the negative electrode active material layer **44** and the positive electrode collector **32** are opposed to each other via only the separator **50** even when misalignment is caused for the negative electrode active material layer **44**. The dimension  $\alpha$  may desirably be designed at a dimension enough to prevent the insulation layer **36** from protruding from the end of the separator **50** in order to avoid poor foil collection of the collector **32** (collector region **32c**).

Examples of the inorganic fillers forming such an insulation layer **36** may include inorganic oxides such as alumina ( $\text{Al}_2\text{O}_3$ ), magnesia ( $\text{MgO}$ ), silica ( $\text{SiO}_2$ ), and titania ( $\text{TiO}_2$ ), clay minerals such as mica, talk, boehmite, zeolite, apatite, and kaolin, and glass materials. Out of these, boehmite ( $\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$ ), alumina ( $\text{Al}_2\text{O}_3$ ), and the like which have stable quality, and further are low-priced, and readily available are preferably used. Incidentally, the parenthesized molecular formula is a typical composition, and the present invention is not necessarily limited to this composition. Any one of these may be included alone, or two or more thereof may be included in combination. As the binders to be included in the insulation layer **36**, for example, various binders usable for the positive electrode active material layer can be preferably used. The proportion of the binder included in the insulation layer **36** is, for example, typically 1 mass % or more, preferably 5 mass % or more, and may be 8 mass % or more, 10 mass % or more, or the like. The binder included in the insulation layer **36** is in an amount of, for example, typically 30 mass % or less, may be 25 mass % or less, or may be 20 mass % or less, 18 mass % or less, or 15 mass % or less. As one typical example thereof, the amount may be appropriately adjusted at 5 to 20 mass %. The thickness of the insulation layer **36** may be typically 20  $\mu\text{m}$  or less, for example, 18  $\mu\text{m}$  or less, 15  $\mu\text{m}$  or less, or 10  $\mu\text{m}$  or less (e.g., less than 10  $\mu\text{m}$ ), or may be set at 8  $\mu\text{m}$  or less, for example, 6  $\mu\text{m}$  or less, or 5  $\mu\text{m}$  or less. The thickness of the insulation layer **36** may be typically 3  $\mu\text{m}$  or more. Incidentally, such an insulation layer **36** may have a weight per unit area of about 0.5  $\text{mg}/\text{cm}^2$  or more, 0.7  $\text{mg}/\text{cm}^2$  or more, 1  $\text{mg}/\text{cm}^2$  or more, or the like, and 1.5  $\text{mg}/\text{cm}^2$  or less, 1.3  $\text{mg}/\text{cm}^2$  or less, 1.2  $\text{mg}/\text{cm}^2$  or less, or the like.

The negative electrode **40** can include typically a negative electrode collector **42**, and porous negative electrode active material layers **44** formed on both surfaces thereof. Specifi-

cally, the negative electrode collector **42** includes an active material layer forming region **42a** and a collector region **42c**. The active material layer forming region **42a** occupies the most part of the negative electrode collector **42**, and the collector region **42c** is adjacent to the active material layer forming region **42a**. The negative electrode collector **42** of this example is long, and is divided in the width direction into the active material layer forming region **42a** and the collector region **42c**. As one example, the dimension in the width direction of the collector region **42c** is about 8 to 12 mm. The negative electrode active material layer **44** is formed in a band shape on the surface of the active material layer forming region **42a**. In the collector region **42c**, the collector is exposed. The pores of the negative electrode active material layer **44** are impregnated with a nonaqueous electrolyte. For the negative electrode collector **42**, for example, metal foil such as copper foil is preferably used.

The negative electrode active material layer **44** contains a particulate negative electrode active material. As the negative electrode active materials, for example, one, or combinations of two or more of carbon type materials such as graphite carbon and amorphous carbon, silicon, lithium transition metal oxide, and lithium transition metal nitride, capable of reversibly occluding/releasing lithium ions are used. The negative electrode active material layer **44** may include, other than the negative electrode active material, a binder such as polyvinylidene fluoride (PVDF), or styrene butadiene rubber (SBR), or a thickener such as carboxymethyl cellulose (CMC), for binding these. The thickness after pressing of the negative electrode active material layer **44** (which is the average thickness of one side; the same shall apply hereinafter.) may be, for example, 20  $\mu\text{m}$  or more, typically 40  $\mu\text{m}$  or more, for example, from the viewpoint of an increase in capacity, 50  $\mu\text{m}$  or more. The average thickness of the negative electrode active material layer **44** may be, for example, 100  $\mu\text{m}$  or less, typically, 80  $\mu\text{m}$  or less, for example, 65  $\mu\text{m}$  or less. Further, the density of the negative electrode active material layer **44** has no particular restriction, and can be set at, for example, 0.8  $\text{g}/\text{cm}^3$  or more, typically, 1.0  $\text{g}/\text{cm}^3$  or more, and 1.5  $\text{g}/\text{cm}^3$  or less, typically, 1.4  $\text{g}/\text{cm}^3$  or less, for example, 1.2  $\text{g}/\text{cm}^3$  or less.

The separator **50** is a constituent element for insulating the positive electrode **30** and the negative electrode **40** from each other, and providing a migration path for electric charge carriers between the positive electrode active material layer **34** and the negative electrode active material layer **44**. Such a separator **50** is arranged between the positive electrode active material layer **34** and the negative electrode active material layer **44**. Such a separator **50** can be preferably formed of a microporous resin sheet including a resin such as polyethylene (PE), polypropylene (PP), polyester, cellulose, or polyamide. Out of these, a microporous sheet including a polyolefine resin such as PE or PP is preferable because the shutdown temperature can be preferably set within the range of 80° C. to 140° C. (typically, 110° C. to 140° C., for example, 120° C. to 135° C.). Such a separator **50** may have a monolayer structure including a single material, or may have a structure of lamination of two or more microporous resin sheets having different material qualities and properties (e.g., average thickness and porosity) (e.g., a three-layered structure in which PP layers are stacked on both surfaces of a PE layer). The thickness (which is the average thickness; the same shall apply hereinafter.) of the separator **50** has no particular restriction, and can be set at, generally 10  $\mu\text{m}$  or more, typically, 15  $\mu\text{m}$  or more, for example, 17  $\mu\text{m}$  or more. Further, the upper limit can be set at 40  $\mu\text{m}$  or less, typically, 30  $\mu\text{m}$  or less, for

example, 25  $\mu\text{m}$  or less. The average thickness of the base material falls within the foregoing range. As a result, the permeability of the electric charge carrier can be kept good, and microscopic short circuit (leakage current) becomes less likely to be caused. For this reason, the input output density and the safety can be combined at a high level.

Incidentally, in the electrode body **20**, the width  $W1$  of the positive electrode active material layer **34**, the width  $W2$  of the negative electrode active material layer **44**, and the width  $W3$  of the separator **50** satisfy the relationship of  $W1 < W2 < W3$ . Further, the negative electrode active material layer **44** covers the positive electrode active material layer **34** at the opposite ends thereof in the width direction, and the separator **50** covers the negative electrode active material layer **44** at the opposite ends thereof in the width direction. Further, the insulation layer **36** covers the positive electrode collector **32** at least in the region opposed to the end of the negative electrode active material layer **44** while being adjacent to the positive electrode active material layer **34**. However, the electrode body of the lithium ion secondary battery **1** herein disclosed is not limited to a wound type electrode body, and may be an electrode body of a so-called flat-plate lamination type, for example, in a form in which a plurality of positive electrodes **30** and negative electrodes **40** are respectively insulated by the separators **50**, and are stacked.

The nonaqueous electrolyte includes a nonaqueous solvent and an electrolyte support salt. The nonaqueous solvent and the electrolyte support salt have no particular restriction on the kind, and may be the same as those used for the electrolyte of a conventional secondary battery. Preferable examples of the electrolyte support salt include lithium salts such as  $\text{LiPF}_6$  and  $\text{LiBF}_4$ . Preferable examples of the nonaqueous solvent include aprotic solvents such as carbonates, esters, and ethers. Out of these, cyclic carbonates such as ethylene carbonate (EC) and propylene carbonate (PC), chain carbonates such as diethyl carbonate (DEC), dimethyl carbonate (DMC), and ethyl methyl carbonate (EMC), and fluorinated chain or fluorinated cyclic carbonates obtained by fluorinating the carbonates are preferably included each alone, or two or more thereof. The concentration of the lithium salt in the electrolyte can be set at, for example, 0.8 to 1.3 mol/L. The nonaqueous electrolyte can include additives such as a film forming agent and an overcharge inhibitor other than these.

The battery case **10** includes a case main body **11** having an opening at a first surface (herein, the top surface), and a lid member **12** for sealing the opening. The case main body **11** of this example is of a flat bottomed square tube type including a bottom surface **11c**, a pair of wide side surfaces **11a** continuous to the bottom surface **11c**, and wide in the width direction, and one narrow side surface **11b** continuous to the bottom surface **11c** and the wide side surface **11a**. The lid member **12** is formed so as to be able to hermetically seal the opening formed by the upper ends of the wide side surface **11a** and the narrow side surface **11b**. The lid member **12** is equipped with a positive electrode external terminal **38T** and a negative electrode external terminal **48T**, an injection hole, and a safety valve. Although the battery case **10** is not limited to this, the battery case **10** is preferably formed of, for example, a metal such as iron, copper, aluminum, or titanium, and an alloy including these (e.g., steel), or a high strength resin.

The positive electrode external terminal **38T** and the negative electrode external terminal **48T** are electrically connected with the positive electrode collector member **38** and the negative electrode collector member **48** provided on

the case inside side, respectively, while being insulated from the lid member **12**. The terminal structures on the positive electrode side and on the negative electrode side are mostly identical with each other. For this reason, below, by taking the positive electrode side as an example, the terminal structure and the collector members **38** and **48** will be described. The following description on the positive electrode collector member **38** similarly applies to the negative electrode collector member **48**. Although the details are omitted, with the terminal structure of a typical secondary battery **1**, as shown in FIG. 2, from the case outside (herein, the top), the positive electrode external terminal **38T**, an external insulation member (not shown), the lid member **12**, an internal insulation member (not shown), and the positive electrode collector member **38** are stacked in this order, and a hole not shown is provided coaxially. Then, a caulking member **38K** (see FIG. 6A) made of a metal, inserted into this hole integrally and tightly caulks these. As a result, each member is fixed to the lid member **12**. Herein, the positive electrode collector member **38** is electrically connected with the positive electrode external terminal **38T** by the caulking member **38K**. The external insulation member and the internal insulation member are mechanically connected with each other by the caulking member **38K**. As a result, the positive electrode external terminal **38T**, the positive electrode collector member **38**, and the caulking member **38K** are electrically insulated from the lid member **12** by the external insulation member and the internal insulation member. Incidentally, the caulking member **38K** may also be previously integrally provided on the top surface of a first portion **38a** of the collector member **38** as shown in FIGS. 6A, 6B, and 6C. The caulking member **38K** is subjected to chalking, so that the protrusion amount from the top surface of the first portion **38a** is reduced (see, FIG. 1, or the like).

The positive electrode collector member **38** includes the first portion **38a** and a second portion **38b**. The first portion **38a** and the second portion **38b** are generally in a sheet shape. The positive electrode collector member **38** is fixed to the lid member **12** of the battery case **10** by the first portion **38a** as described above. The second portion **38b** is continuous to the first portion **38a**, and is bent with respect to the first portion **38a**. The portion between the first portion **38a** and the second portion **38b** is a bent part **38L**. The positive electrode collector member **38** of the present embodiment is bent to about  $90^\circ$  at the bent part **38L**. The second portion **38b** extends downwardly along the wide side surface **11a** of the case main body **11**. The second portion **38b** is curved in a substantially S shape inwardly of the battery case **10** at a prescribed-length downward extension thereof. Then, at the end **38e** under the curved part **38S**, the second portion **38b** extends downwardly along the wide side surface **11a** again. The second portion **38b** is bonded with the collector region **32c** of the wound type electrode body **20** at the flat-sheet-shaped end **38e** under the curved part **38S**. With such a configuration, the positive electrode collector member **38** can be configured as follows: the curved part R of the wound type electrode body **20** can be arranged in the space formed between the first portion **38a** and the curved part **38S**, so that the wound type electrode body **20** can be supported and fixed without breaking the curved part R. Incidentally, the positive electrode collector member **38** and the collector region **32c** of the electrode body **20** are preferably connected with each other by ultrasonic welding. Further, the negative electrode collector member **48** and the collector region **42c** of the electrode body **20** are preferably connected with each other by resistance welding. As a result, in the secondary battery **1**, an electric energy can be charged to the electrode

body 20, and an electric energy can be extracted from the electrode body 20 to an external circuit through the positive electrode external terminal 38T and the negative electrode external terminal 48T.

The positive electrode collector member 38 further includes a rib 38c connected to the first portion 38a and the second portion 38b at the bent part 38L. The rib 38c is a small-piece-shaped portion. The rib 38c is, as shown in FIG. 3A, placed across the first portion 38a and the second portion 38b. The rib 38c is disposed so as to be orthogonal to at least one, preferably both of the first portion 38a and the second portion 38b. In the present embodiment, the rib 38c is connected to the surfaces of the first portion 38a and the second portion 38b each on the side thereof opposed to the electrode body 20. Such a configuration can preferably suppress the second portion 38b from relatively rocking with respect to the first portion 38a. In other words, the first portion 38a and the second portion 38b are suppressed from being deformed in a direction in which the mutually formed angle ( $\theta$ ) decreases (e.g.,  $\theta < 90^\circ$ ) and a direction in which the angle increases (e.g.,  $\theta > 90^\circ$ ).

Although such a rib 38c is not limited thereto, preferably, the first portion 38a, the second portion 38b, and the rib 38c are continuously and integrally formed. Namely, although the first portion 38a, the second portion 38b, and the rib 38c of the positive electrode collector member 38 may be formed of different members bonded together, these may be formed by processing one sheet-shaped metal member by at least one of bending and pressing. In other words, the positive electrode collector member 38 may be at least one of a bent product and a pressed product. As a result, a joint is not formed at the first portion 38a, the second portion 38b, and the rib 38c. This is preferable because when a vibration is applied to the secondary battery 1, a fault such as breakage of the joint due to stress concentration to the joint is accordingly less likely to be caused. Incidentally, any those skilled in the art can confirm whether the first portion 38a, the second portion 38b, and the rib 38c of the positive electrode collector member 38 are manufactured by bending and/or pressing or not by observing the metal structure.

Below, the results of a study on the shapes of the ribs 38c and 48c of the collector members 38 and 48 will be shown, and preferable shapes of the ribs 38c and 48c will be described.

As shown in FIG. 3A, for each length of the second portions 38b and 48b of the collector members 38 and 48, the distance from (each surface on the rib side of) the first portions 38a and 48a to each extreme end of the ends 38e and 48e of the second portions 38b and 48b is referred to as the length  $L_C$  (distance  $L_C$ ) of the second portions 38b and 48b. Namely, the length  $L_C$  of the second portion 38b or 48b is the dimension not in view of the curve length of the curved part 38S. Whereas, for each thickness of the second portions 38b and 48b, each dimension of the second portion 38b and 48b in a direction orthogonal to the wide side surface 11a is referred to as the thickness  $T_C$  (mm). For each length of the ribs 38c and 48c, each dimension of the ribs 38c and 48c in a direction along the length  $L_C$  is referred to as the length  $L_R$  (mm) of the ribs 38c and 48c. For each thickness of the ribs 38c and 48c, the dimension in a direction in parallel with the wide side surface 11a is referred to as the thickness  $T_R$  (mm) of the ribs 38c and 48c. For each width of the ribs 38c and 48c, the dimension in a direction along the thickness  $T_C$  of the second portions 38b and 48b is referred to as the width  $W_R$  (mm).

Rib Length

For the collector member with the length  $L_R$  of the rib changed in five ways, and also for the collector member not provided with a rib, a vibration test was conducted under the following conditions, thereby measuring the displacement amount of the extreme end of the second portion. The results are shown in Table 1 below as relative values with the displacement amount of the extreme end of the second portion when the vibration test was conducted for the collector member without a rib as "100". Then, the case where the relative value of the displacement amount is 20 or less is assumed as a sufficient vibration suppressing effect (success: "AA" in Table 1), and the case where the relative value of the displacement amount is more than 20 is assumed as an insufficient vibration suppressing effect (failure: "CC" in Table 1).

Incidentally, the thickness  $T_R$  of the rib of the collector member was assumed to be constant at "0.4/ $T_C$ " with respect to the thickness  $T_C$  of the second portion, and the width  $W_R$  of the rib was assumed to be constant at "0.47/ $T_C$ " with respect to the thickness  $T_C$  of the second portion.

Vibration Test Conditions

Acceleration: 10 G

Frequency: 25 Hz

Temperature: room temperature (25° C.)

Vibration direction: width direction of rib (thickness direction of second portion)

TABLE 1

Sample	1	2	3	4	5	6
Rib length $L_R$	None	0.04 $L_C$	0.07 $L_C$	0.10 $L_C$	0.13 $L_C$	0.16 $L_C$
Displacement amount [—]	100	70	50	20	15	10
Evaluation	CC	CC	CC	AA	AA	AA

As shown in Table 1, it has been confirmed as follows: by setting the length  $L_R$  of the rib at 0.1 time or more ( $L_R \geq 0.1 \times L_C$ ) with respect to the length  $L_C$  of the second portion, it is possible to effectively suppress the vibration. Although not specifically shown, the same tendency can also be observed for the case where the test is conducted for a collector member having different specifications such as shape and dimension. The length  $L_R$  of the rib is preferably  $L_R \geq 0.12 \times L_C$ , more preferably  $L_R \geq 0.15 \times L_C$ , or  $L_R \geq 0.2 \times L_C$ , and may be set at, for example,  $L_R \geq 0.3 \times L_C$ , or  $L_R \geq 0.5 \times L_C$ . The upper limit of the length  $L_R$  of the rib can be determined in view of the allowable dimension of the battery case within the range in which the curved part R of the electrode body 20 and the rib do not interfere with each other. For example, the upper limit of the length  $L_R$  of the rib may be  $1 \times L_C$ , and examples thereof may include about  $0.9 \times L_C$  and  $0.8 \times L_C$ .

Rib Thickness

For the collector members with the thickness  $T_R$  of the rib changed in six ways, and also for the collector member not provided with a rib, a vibration test was conducted under the same conditions as those described above, thereby measuring the displacement amount of the extreme end of the second portion. The results are shown in Table 2 below as relative values with the displacement amount of the extreme end of the second portion when the vibration test was conducted for the collector member without a rib as "100". Then, the case where the relative value of the displacement amount is 20 or less is assumed as a sufficient vibration suppressing effect (success: "AA" in Table 2), and the case where the relative value of the displacement amount is more

13

than 20 is assumed as an insufficient vibration suppressing effect (failure: "CC" in Table 2).

Incidentally, the length  $L_R$  of the rib of the collector member was assumed to be constant at "0.1x $L_C$ " with respect to the thickness  $T_C$  of the second portion, and the width  $W_R$  of the rib was assumed to be constant at "0.47/ $T_C$ " with respect to the thickness  $T_C$  of the second portion.

TABLE 2

Sample	1	2	3	4	5	6	7
Rib thickness $T_R$	0	0.1/ $T_C$	0.2/ $T_C$	0.4/ $T_C$	0.48/ $T_C$	0.56/ $T_C$	0.8/ $T_C$
Displacement amount [—]	100	50	40	20	20	15	15
Evaluation	CC	CC	CC	AA	AA	AA	AA

As shown in Table 2, it has been confirmed as follows: by setting the thickness  $T_R$  of the rib at 0.4 time or more ( $T_R \geq 0.4 \times 1/T_C$ ) with respect to the inverse ( $1/T_C$ ) of the thickness  $T_C$  of the second portion as shown in, for example, Table 2, it is possible to effectively suppress the vibration. Although not specifically shown, roughly the same tendency can also be observed for the case where the test is conducted for a collector member having different specifications such as shape and dimension. This thickness  $T_R$  of the rib is preferably  $T_R \geq 0.45/T_C$ , more preferably  $T_R \geq 0.48/T_C$ , and may be, for example,  $T_R \geq 0.5/T_C$ ,  $T_R \geq 0.55/T_C$ ,  $T_R \geq 0.6/T_C$ ,  $T_R \geq 0.7/T_C$ , or  $T_R \geq 0.8/T_C$ . The upper limit of the thickness  $T_R$  of the rib can be determined in view of the processability of the collector member, the connectivity with the electrode body, and the like. As one example, when the rib is too thick, it becomes difficult to form the rib by extrusion. Further, when the rib is too thick, the connection between the electrode body and the collector member may become difficult. From such viewpoints, the upper limit of the thickness  $T_R$  of the rib may be set, for example, with about  $1/3$  the width of the collector member (the dimension in the direction orthogonal to the length  $L_C$  and the thickness  $T_C$ ) as a guide. The thickness  $T_R$  of the rib may be  $2/3$  or less,  $1/4$  or less,  $1/5$  or less the width of the collector member, or the like.

Rib Width

For the collector members with the width  $W_R$  of the rib changed in six ways, and also for the collector member not provided with a rib, a vibration test was conducted under the same conditions as those described above, thereby measuring the displacement amount of the extreme end of the second portion. The results are shown in Table 3 below as relative values with the displacement amount of the extreme end of the second portion when a vibration test was conducted for the collector member without a rib as "100". Then, the case where the relative value of the displacement amount is 20 or less is assumed as a sufficient vibration suppressing effect (success: "AA" in Table 3), and the case where the relative value of the displacement amount is more than 20 is assumed as an insufficient vibration suppressing effect (failure: "CC" in Table 3).

Incidentally, the length  $L_R$  of the rib of the collector member was assumed to be constant at "0.1x $L_C$ " with respect to the length  $L_C$  of the second portion, and the thickness  $T_R$  of the rib was assumed to be constant at "0.4/ $T_C$ " with respect to the thickness  $T_C$  of the second portion.

14

TABLE 3

Sample	1	2	3	4	5	6	7
Rib thickness $W_R$	0	0.17/ $T_C$	0.25/ $T_C$	0.33/ $T_C$	0.47/ $T_C$	0.58/ $T_C$	0.83/ $T_C$
Displacement amount [—]	100	60	20	20	15	15	10
Evaluation	CC	CC	AA	AA	AA	AA	AA

As shown in Table 3, it has been confirmed as follows: by setting the width  $W_R$  of the rib at 0.25 time or more ( $W_R \geq 0.25 \times 1/T_C$ ) with respect to the inverse ( $1/T_C$ ) of the thickness  $T_C$  of the second portion, it is possible to effectively suppress the vibration. Although not specifically shown, the same tendency can also be observed for the case where the test is conducted for a collector member having different specifications such as shape and dimension. The width  $W_R$  of the rib is preferably  $W_R \geq 0.3/T_C$ , more preferably  $W_R \geq 0.4/T_C$ , or  $W_R \geq 0.5/T_C$ , and may be, for example,  $W_R \geq 0.6/T_C$ ,  $W_R \geq 0.8/T_C$ , or  $W_R \geq 1/T_C$ . The upper limit of the width  $W_R$  of the rib can be determined in view of the processability of the collector member, the accommodability in the case, and the like. As one example, when the width  $W_R$  of the rib is too large, it becomes difficult to form the rib by extrusion. Further, a too large width  $W_R$  of the rib may cause interference between the case covering the electrode body, an insulation film (not shown), or the like and the rib upon accommodating the electrode body in the case or in the case, and hence is not preferable. From such a viewpoint, the upper limit of the width  $W_R$  of the rib can be set at a dimension capable of avoiding such interference. The width  $W_R$  of the rib may desirably be set to be, for example, about  $1/2$ , or may desirably be set about  $1/3$  or less the thickness of the electrode body (the dimension in each direction orthogonal to the winding axis WL and the height direction H). Further, the width  $W_R$  of the rib may desirably be set to be, for example, about  $1/2$ , or also may be desirably set at about  $1/3$  or less the dimension of the second portion in the thickness direction (each direction orthogonal to the winding axis WL and the height direction H).

In the embodiment, the rib 38c was, as shown in FIG. 3A, a rectangular sheet-shaped body as seen from the direction along the wide side surface 11a. However, the shape of the rib 38c is not limited to this. For example, the rib 38c may lack the end of the portion connected to the first portion 38a and the second portion 38b in the region opposite to the bent part 38L across the line connecting two ends opposite to the bent part 38L. For example, the rib 38c may be a triangle formed by connecting the bent part 38L and the two ends on the opposite side, respectively. Further, for example, for the rib 38c, the corner part not connected to the first portion 38a and the second portion 38b may be subjected to chamfering. The chamfering may be chamfering of one corner part of the rectangle into an R surface or a C surface, or may be chamfering into an R surface so as to gently connecting the two ends on the opposite side (i.e., to form the rectangle into a fan shape). Further, in the example shown in FIG. 3B, the rib 38c is provided so as to be connected to the end of the second portion 38b on the side thereof farther from the center in the width direction of the battery case. However, the position of the rib 38c is not limited to this. The rib 38c may be provided at the end of the second portion 38b closer to the center in the width direction of the battery case, or may be provided so as to be connected to the center in the width direction of the second portion 38b, or to other positions.

In the embodiment, only respective ones of ribs **38c** and **48c** are provided at the collector members **38** and **48**, respectively. However, respective two or more of the ribs **38c** and **48c** may be provided at respective ones of the collector members **38** and **48**, respectively. For example, in the example shown in FIG. 3B, one rib **38c** is provided at one positive electrode collector member **38**. However, the number of the ribs **38c** is not limited to this. Two or more, for example, a plurality of such as two, three, or four ribs **38c** may be provided at one positive electrode collector member **38**. In this case, all the ribs **38c** may have the same shape, or one or some ribs **38c** may independently have different shapes. When there are a plurality of ribs **38c**, respective ribs **38c** may be desirably arranged dispersed in the width direction (W) of the second portion **38b** so as to preferably suppress the fluctuations in angle formed between the first portion **38a** and the second portion **38b**. For example, the ribs **38c** may be arranged at regular intervals in the width direction of the second portion **38b**. Incidentally, when the first portion **38a** and the second portion **38b** are connected to each other not in an L shape in cross section but in a T shape in cross section at the bent part **38L** thereof, the ribs **38c** may be provided at only one surface of the second portion **38b**, or may be provided at both surfaces thereof (see FIG. 6B). In this case, for each thickness  $T_R$  and each width  $W_R$  of the ribs **38c** and **48c**, each total thickness  $T_R$  and each total width  $W_R$  of respective two or more ribs **38c** and **48c** preferably fall within the respective ranges.

In the embodiment, the second portions **38b** and **48b** of the collector members **38** and **48** were each in the shape of a rectangle (in the shape of a band) longer in the height direction as seen from the side of the wide side surface. However, each shape of the second portions **38b** and **48b** as seen from the side of the wide side surface may also be in other shapes than a rectangle. For example, at each portion closer to the bent parts **38L** and **48L**, each width of the second portions **38b** and **48b** may be larger, and the first portions **38a** and **48a** and the second portions **38b** and **48b** may be connected to each other, respectively, at a longer dimension. Then, each width of the second portions **38b** and **48b** may continuously or stepwise narrow with approach toward bottom (see FIG. 6A).

Further, the second portions **38b** and **48b** were provided along the wide side surface of the battery case **10**. However, the second portions **38b** and **48b** may be provided along the narrow side surface of the battery case **10**. In this case, the second portions **38b** and **48b** may be further bent, thereby to be bonded to the collector regions **32c** and **42c** of the electrode body **20**, respectively. For example, for the second portions **38b** and **48b**, as shown in FIG. 6C, at least the lower portions thereof to be bonded to the collector regions **32c** and **42c** of the electrode body **20** each may be bifurcated by a slit. When each lower end of the second portions **38b** and **48b** is bifurcated, the collector part of the wound type electrode body **20** can be divided into two parts with reference to the winding axis WL, and bound, respectively. These can be connected to respective bifurcated portions of the second portion **38b** in a divided manner, respectively. With such a configuration, in bonding between the wound type electrode body **20** and the collector members **38** and **48**, the deformation amount and the load applied to the collector regions **32c** and **42c** can be reduced. Further, this is also preferable in that the impregnation of the electrolyte into the wound type electrode body **20** can be promoted. Incidentally, in this case, the ribs **38c** and **48c** may be desirably provided one each above respective centers in respective width directions of respective bifurcated portions of the

second portions **38b** and **48b** (the width direction of the narrow side surface, the thickness direction of the battery case). Provision of respective ones of the ribs **38c** and **48c** at respective second portions **38b** and **48b** is also preferable in terms of enhancing the strengths of the second portions **38b** and **48b**.

In the embodiment, the electrode body was a wound type electrode body. However, the electrode body may be a sheet type electrode body. When the electrode body is a sheet type electrode body, as shown in FIG. 6B, the second portions **38b** and **48b** of the collector members **38** and **48** are each not required to have the curved part **38S**. Also in that case, the dimensions of the ribs **38c** and **48c** preferably fall within the foregoing range.

In the embodiment, for the collector members **38** and **48**, the second portions **38b** and **48b** were set so as to extend downwardly along the wide side surface. However, the aspect of attaching the collector members **38** and **48** to the battery case **10** is not limited to this. For example, the second portions **38b** and **48b** of the collector members **38** and **48** may be set so as to downwardly extend along the narrow side surface. In this case, as shown in FIG. 6C, the second portions **38b** and **48b** may be bonded at their respective two parts to the collector regions **32c** and **42c** of the electrode body, respectively. For example, as seen from the narrow side surface side, the second portions **38b** and **48b** are each bifurcated into two parts extending downwardly, and the wound type electrode body **20** is divided into two parts on the 3 o'clock side and the 9 o'clock side along the winding axis WL. Then, respective ones of the bifurcated parts of the second portions **38b** and **48b** may be bonded to the electrode body **20** on the 3 o'clock side, and respective others of the bifurcated parts may be bonded to the electrode body **20** on the 9 o'clock side. At this step, the ribs **38c** and **48c** may be provided, one for each of respective bifurcated parts of the second portions **38b** and **48b**. Further, the bifurcated parts of the second portions **38b** and **48b** may be respectively twisted so as to be in parallel with the collector regions **32c** and **42c**, and to be bonded to the collector regions **32c** and **42c**, respectively.

Up to this point, the present invention was described in details. However, these are merely illustrative, and do not limit the appended claims. The technology described in the appended claims include various modifications and changes of the foregoing specific examples.

What is claimed is:

1. A secondary battery, comprising:

- a battery case;
- an electrode body in which a positive electrode, a negative electrode, and a separator are stacked, with the positive electrode and the negative electrode being insulated from each other by the separator; and
- a collector member connected to the battery case and the electrode body, wherein
  - the positive electrode includes
    - a positive electrode collector including an active material layer forming region, an insulation layer forming region adjacent to the active material layer forming region, and a collector region adjacent to the insulation layer forming region,
    - a positive electrode active material layer including a positive electrode active material provided on a surface of the active material layer forming region, and
    - an insulation layer provided on a surface of the insulation layer forming region,

17

the collector member includes a first portion, and a second portion continuous to the first portion and bent relative to the first portion,  
 the first portion is fixed to the battery case,  
 the second portion is connected, at an end thereof on an opposite side to the bent portion, to the collector region,  
 the collector member further including a rib integrally formed, at the bent part, with the first portion and the second portion;  
 wherein the rib has a length that is shorter than a space between a top of the electrode body and the first portion of the collector member, and a width that is half or less than a thickness of the electrode body;  
 wherein the rib is connected, among surfaces of the first portion and the second portion, to a surface on an opposite side to the electrode body; and  
 wherein the collector member includes the first portion, the second portion, and the rib, which are continuously and integrally formed, and is at least one of a bent product and a pressed product of a sheet-shaped metal.

2. The secondary battery according to claim 1, wherein the battery case is a square battery case including a case main body having an opening, and a lid member for covering the opening,  
 the first portion is connected to an inner surface of the lid member,  
 the second portion is bent along any one surface of the case main body surrounding the opening, and  
 a length ( $L_c$ ) of the collector member from the first portion to an extreme end of the end of the collector member and a length ( $L_R$ ) of a dimension of the rib in a direction along the length ( $L_c$ ) satisfy following relationship:  
 $L_R \geq 0.1 \times L_c$ .

18

3. The secondary battery according to claim 1, wherein the battery case is a square battery case including a case main body having an opening, and a lid member for covering the opening,  
 the first portion is connected to an inner surface of the lid member,  
 the second portion is bent along any one surface of the case main body surrounding the opening,  
 a thickness ( $T_c$ ) of a dimension of the collector member in a direction orthogonal to the one surface of the second portion and a thickness ( $T_R$ ) of a dimension in a direction in parallel with the one surface of the rib satisfy following relationship:  $T_R \geq 0.4 \times 1/T_c$ .

4. The secondary battery according to claim 1, wherein the battery case is a square battery case including a case main body having an opening, and a lid member for covering the opening,  
 the first portion is connected to an inner surface of the lid member,  
 the second portion is bent along any one surface of the case main body surrounding the opening,  
 a thickness ( $T_c$ ) of a dimension in a direction orthogonal to the one surface of the second portion and a width ( $W_R$ ) of a dimension of the collector member in a direction along the thickness ( $T_c$ ) of the rib satisfy following relationship:  $W_R \geq 0.25 \times 1/T_c$ .

5. The secondary battery according to claim 1, wherein the electrode body is a wound type electrode body in which the positive electrode, the negative electrode, and the separator which are lengthy are stacked and wound.

\* \* \* \* \*